Indoor Air Quality

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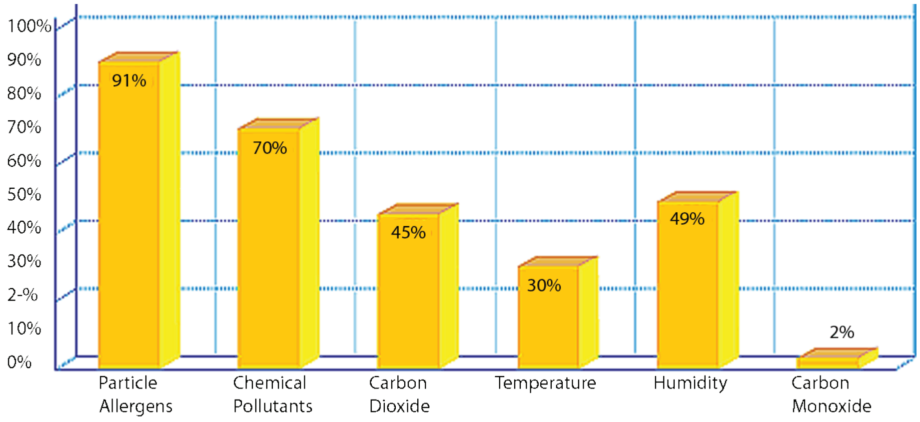

Fig. 01 Percentage of North American homes with common indoor air quality problems

Introduction

While traditionally people have been concerned about exposure to outdoor air pollution, changes in our ways of life and the ways we build have made air within our buildings more polluted than the outdoor air, even in most cities. “EPA’s Total Exposure Assessment Methodology (TEAM) studies found levels of about a dozen common organic pollutants to be 2 to 5 times higher inside homes than outside, regardless of whether the homes were located in rural or highly industrial areas.”[1] People now spend approximately 90 percent of their time indoors, and the prolonged exposure to indoor pollutants increases the health risks. Furthermore, there has been a dramatic increase in the chemical content of building materials, furnishings and household products. Compounding this problem is recent trend to produce highly sealed buildings to reduce energy loss through infiltration. The term indoor air quality (IAQ), includes the environmental characteristics inside buildings such as the concentrations of pollutants, the air temperature, humidity, and the ventilation rate which affect human health, comfort, or work performance.[2]

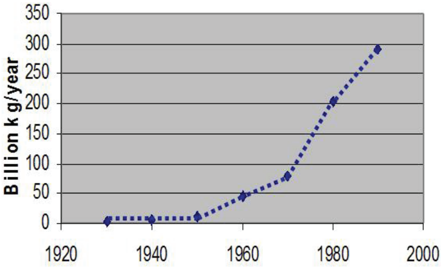

Fig. 02 Global Production of Synthetic Chemicals

Health

The effects of indoor pollutants on human health are known as sick building syndrome (SBS) symptoms or building related symptoms (BRS) and often include eye, nose or throat irritation, skin irritation, cough, wheeze, headache, and fatigue

Contaminants	**Indoor Sources**	**Potential Health Effects**
Respirable Particles	Tobacco smoke, cooking, unvented combustion appliances, aerosol sprays, condensation of vapors, resuspended housedust	Depending on particle composition: mucous membrane irritation, respiratory infections, emphysema, heart disease, lung cancer.
Formaldehyde	Particleboard, plywood, insulation, furnishings, adhesives, synthetic building materials, tobacco smoke.	Mucous membrane irritation, skin rash, chemical sensitivity, lower respiratory irritation, pulmonary edema, central nervous system effects, possible human carcinogen.
Microorganisms (Bacteria, Viruses, Fungi)	Air-cooling equipment, humidifiers, flush toilets, carpeting, people, pets, plants.	Acute respiratory infections (e.g., influenza, Legionnaire's disease, Pontiac Fever, Q Fever).
Aeroallergens (Allergic Agents)	Plant pollen, animal dander, insect parts, house dust, molds, mites, algae, detergents, chemical additives.	Allergic reaction, pneumonitis.
Combustion Gases (CO and N02)	Unvented combustion appliances, attached garages, woodstoves, fireplaces, tobacco smoke.	CO: oxygen deprivation due to COHb, impaired vision and brain function, fatal at high concentrations. N02: increased respiratory infection rate, bronchoconstriction, pulmonary edema.
Radon	Underlying soil, building construction materials, well water.	Lung cancer.
Organic Vapors	Solvents, adhesives, synthetic building materials, aerosol sprays, pesticides, cooking, furnishings, paint, metabolic processes, tobacco smoke.	Mucous membrane irritation, narcotic at high concentrations, central nervous system effects, damage to heart, kidney, and liver, many documented or suspected human carcinogens.
Fibers (Asbestos, Mineral, Synthetic)	Insulation, fire retardants, building construction materials, furnishings, texture paints.	Skin irritation, mucous membrane irritation; asbestos is associated with increased incidences of lung cancer, pleural and peritoneal mesotheliomas, and gastrointestinal tract cancer.

Fig. 03 Summary of Major Contaminents

symptoms.[3] Chronic exposure may lead to increased mortality, as well as a decrease in productivity and in the ability to learn; the most susceptible include the young, the elderly, and the chronically ill.[4] The health effects are related to the exposure, calculated as the product of pollutant concentration present in each unit volume of air in the breathing zone of a space and time the person spends in the space.[5] The problem is complicated by the fact that building occupants may be suffering from irreversible health effects and yet exhibit no symptoms at the present time since many diseases have latency periods of ten years or more.[6]

Comfort

Comfort aspects related to IAQ include thermal, olfactory and sensory comfort.[7] Thermal incompatibility, unpleasant odors, or lack of air movement create poor indoor environments. Only some contaminants may be directly sensed by the occupants while others may be unnoticed until more serious symptoms occur.

Performance

Studies have measured 4% to 16% increases in the performance of certain office work tasks when indoor pollutant sources were removed. Better perceived indoor air quality is correlated with a 1% increase in task performance per each 10% decrease in the percentage of occupants dissatisfied with indoor air quality.[8]

Energy

Air-exchange rates are have been reduced in order to create more energy-efficient buildings, however this has also caused a buildup of indoor air pollution. Air-to-air heat exchangers may allow for maintenance of both indoor air quality and energy conservation.[9]

Sources

Indoor pollutants come from a variety of sources: combustion, building materials and furnishings, cleaning and maintenance products, HVAC systems, biological contaminants, and outdoor sources. The relative significance of the source is directly related to how much of the pollutant it emits and how hazardous those emissions are. For some sources, the age of the source and whether it is properly maintained are significant factors in its levels of emissions. Sources like building materials, furnishings, and household products release pollutants continuously while others may be related to activities

Control Measure Description	Pollutant	Example
Ventilation: Dilution of indoor air with fresh outdoor air or recirculated filtered air, using mechanical or natural methods to promote localized, zonal, or general ventilation.	Radon and radon progeny: combustion by-products; tobacco smoke; biological agents (particles).	Local exhaust of gas stove emissions; air-to-air heat exchangers; building ventilation codes; venting sub-slab area to remove radon gas or volatile organic compounds.
Source removal or substitution: Removal of indoor emission sources or substitution of less hazardous materials or products.	Organic substances; asbestiform minerals; tobacco smoke.	Restrictions on smoking in public places; removal of asbestos.
Source modification: Reduction of emission rates through changes in design or processes; containment of emissions by barriers or sealants.	Radon and radon progeny: organic substances; asbestiform minerals; combustion by-products.	Plastic barriers to reduce radon levels; containment of asbestos; design of buildings without basements to avoid radon; catalytic oxidation of CO to CO_2 in kerosene burners.
Air cleaning: Purification of indoor air by gas adsorbers, air filters, and electrostatic precipitators.	Particulate matter: combustion by-products; biological agents (particles).	Residential air cleaners to control tobacco smoke or wood smoke; ultraviolet irradiation to decontaminate ventilation air; formaldehyde-sorbant filters.
Behavioral adjustment: Reduction in human exposure through modification of behavior patterns; facilitated by consumer education, product labeling, building design, warning devices, and legal liability.	Organic substances: combustion by-products, tobacco smoke.	Smoke-free zones; architectural design of interior space; certification of formaldehyde concentrations for home purchases.

Fig. 04 Summary of Mitigating Measures

and therefore release pollutants intermittently.[10]

Combustion

Combustion products such as un-vented kerosene and gas space heaters, woodstoves, fireplaces, and gas stoves release carbon monoxide, nitrogen dioxide, and particles. Combustion gases and particles also come from improperly installed or maintained chimneys and flues and damaged furnace heat exchangers. In weatherized homes, fireplaces and woodstoves with no dedicated outdoor air supply can back-drafted pollutants into the living space, particularly. At high concentrations carbon-monoxide can cause unconsciousness and death, while at lower concentrations it can cause headaches, dizziness, weakness, nausea, confusion, and disorientation, to fatigue. Nitrogen dioxide irritates the mucous membranes in the eye, nose, and throat, causes shortness of breath and increases the risk of respiratory infection.[11]

Formaldehyde

Formaldehyde is a chemical used widely to manufacture building materials and household products as well as a by-product of combustion. The most significant sources of formaldehyde are likely to be pressed wood products that contain urea-formaldehyde (UF) resins, including particleboard, hardwood plywood paneling, and medium density fiberboard. Other pressed wood products produced for exterior construction, such as softwood plywood and flake or oriented strandboard, use phenol-formaldehyde (PF) resin which emits formaldehyde at lower rates. Formaldehyde emissions generally decrease as products age and high indoor temperatures or humidity increase the release of formaldehyde in new products. High concentrations trigger asthma attacks, some people can develop a sensitivity to formaldehyde, and it may cause cancer.[12]

Volatile Organic Compounds

Volatile organic compounds (VOC's) are carbon-containing chemicals that are gases at room temperature, and are suspected causes of a broad range of health effects including, such as sensory irritation symptoms, allergies and asthma, neurological and liver toxicity, and cancer. VOC's are emitted many common indoor sources and produced from chemical reactions of indoor ozone with other VOC's, or materials like carpeting. While outdoor air is the major source of ozone, additional sources include: "ozone generators (marketed as air cleaners), electronic air cleaners (that unintentionally produce ozone as a by-product), and some types of office equipment." [13]

Radon

Radon, a cause of lung cancer, is produced by the uranium in the soil or rock on which homes are built, entering the home as a gas through dirt floors, cracks in concrete walls and floors, floor drains, and sumps.

Fig. 05 Mold Gorwth

Radon problems can occur in any home new or old, well-sealed or drafty homes, with or without a basement.[14]

Biological Contaminants

Biological contaminants include bacteria, molds, mildew, viruses, animal dander and cat saliva, house dust mites, cockroaches, and pollen. Particles contain allergens or toxic chemicals with the potential to cause respiratory issues and inhibited immune system function or effects on the central nervous system. Microorganisms can also release microbial volatile organic compounds. High indoor air humidity increases the levels of house dust mites and house dust mite allergens. [15]

Molds

Aside from health issues, mold can produce odors as well as effect the look of items it has attached itself to and is starting to destroy. Mold can be very destructive if not prevented, and if not maintained once discovered “with respect to wood frame buildings can affect the structural integrity of the building.”[16]

Molds are tiny spores that are impossible to completely eliminate, making them one of the more abundant and problematic issues regarding indoor air quality. Spores continually move about through indoor and outdoor air. The moment the spores land on a damp spot indoors they begin to grow. While the spores themselves are impossible to fully eliminate, the focus then turns to preventing the amount of spores within the air, as well as minimizing the amount of moisture within the building.[17]

Improving Air Quality

There are a variety of strategies for improving indoor air quality that range from addressing the source, to reducing the build-up of contaminants, to modifying behavior. Removing or avoiding contaminant sources has obvious benefits for indoor air quality, yet alternatives are not always available and may have adverse effects of their own. Another option is modifying the source to reduce its emissions, which is most effective for combustion type sources.[18]

Moisture Control

One problem that contributes to moisture build-up within buildings occurred after a change in building practices in the 1970s that “resulted in tightly sealed buildings with diminished ventilation, contributing to moisture vapor buildup.”[19] Other problems are related to systems and designs that pass water through a building, do not perform effectively, such as gutters, drains, etc., or allow water under a building.

Many solutions are directly related to their corresponding problems. For example, repair plumbing leaks as soon as possible. If drainage around the building is allowing water to pond near the foundation, re-route the drainage paths away from the building. Reduce “condensation by increasing surface temperature or reducing the moisture level in the air.”[20] However, there are several solutions such as maintaining proper humidity levels, increasing air circulation, and venting kitchens and bathrooms that rely on a common technique, ventilation.[21]

Ventilation

While ventilation is a simple, and easily understandable method for creating more desirable indoor air quality, there are many issues it can bring as well. Although many buildings are designed to accommodate natural air flows through and around the building, there are many situations that are

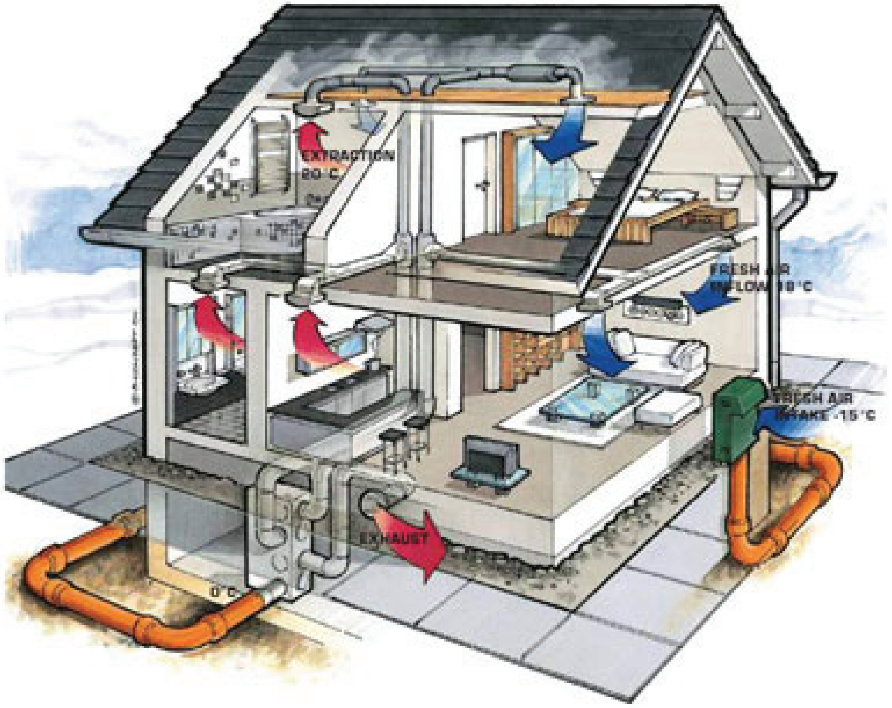

Fig. 06 Ventilation within a building

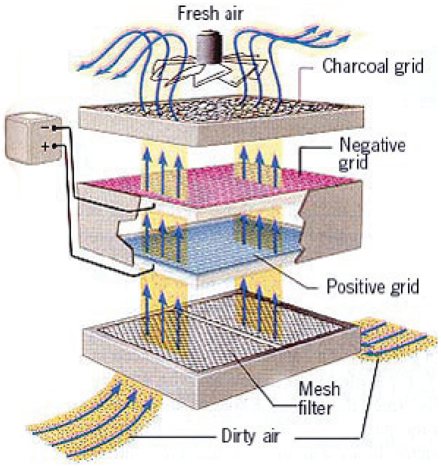

Fig. 07 Electrostatic precipitation filter

not conducive to efficient ventilation. Ventilation may be deficient in "confined spaces, facilities failing to provide adequate maintenance of ventilation equipment, facilities operated to maximize energy conservation, windowless areas, and areas with high occupant densities."[22]

Ventilation Systems:

Dilution: A general exhaust ventilation system is a form of exposure control that involves providing enough air in the workplace to dilute the concentration of airborne contaminants [i.e. odors and particulates] to acceptable levels. By introducing more fresh air into a space, the percentage of contaminated air decreases, improving the overall indoor air quality.

Local Exhaust: An industrial ventilation system that captures and removes emitted contaminants before dilution into the ambient air of the workplace. This system cleans the exhaust air before introducing it back into the space.

Makeup Air: Also called Replacement and Compensating Air, is air supplied to a space to replace exhausted air.

HVAC: Ventilating systems designed primarily to control temperature, humidity, odors, and air quality. (Primarily for comfort)

Building ventilation uses a combination of the above systems. The more systems used in conjunction with each other, the more efficient (assuming proper calibration and maintenance) the overall ventilation. Two common HVAC systems used in public and commercial buildings are constant volume and variable air volume. Constant volume systems "provide a constant airflow [and vary] the air temperature to meet heating and cooling needs. The percentage of outdoor air may be held constant, but is often controlled either manually or automatically to vary with outdoor temperature and humidity."[23] Variable air volume systems vary the airflow into occupied areas while maintaining a constant temperature.

Providing more air to a room can put the room under positive pressure. If less air is supplied to a room than is being exhausted then the room will be under negative pressure. Negative pressure can result in unfiltered outdoor air seeping into the building through any cracks in the building envelope (seams, windows, etc.). Positive pressure in turn can push air out through the same means as air can seep in, preventing particulates and unfiltered air from entering a building.[24]

While ideas of natural ventilation such as the stack and effect and natural wind flows are considered as alternative means to using HVAC systems, these natural process can overpower a building's mechanical system. Interruption of air circulation and ventilation is possible in buildings with leaky envelopes. The stack effect's process pulls hot air from the top of the building and replaces (pulls in) cooler air from the bottom. This in turn introduces unfiltered air into the building.[25]

While moving and mixing indoor and outdoor air are necessary for proper ventilation there arises an issue of pollutants in the outdoor air. Air cleaning methods include particulate filtration-filters, electrostatic precipitation, negative ion generation, and gas sorption-binding. Filtration filters are simple filters whose porosity allows/restricts airflow and particulates of various sizes. Electrostatic precipitation charges particles an opposite charge of the filter, such that as the particles pass over the filter they are attracted and retained. Negative ion generation charges passing particulates so that their static nature will attract and adhere them to surfaces within the room. This reduces the amount of particulates in the air, and allows for easy cleaning. Gas sorption-binding pairs particulates that act as gases with a binding agent that helps with the particulates filtration.[26] A lack of hygienic regimes within HVAC ducts and equipment can lead to anthropogenic diseases such as Legionellosis. Symptons include high fever, chills, and cough, but have been known to include muscle aches, and headaches.[27]

Conclusion

Buildings cannot be sustainable if they adversely effect the health of the occupants. Where possible materials and products that emit or serve as hosts for harmful substances should be avoided, adequate air exchanges should be provided, and air temperatures and humidity levels regulated to reduce the build up of toxins and irritants. Indoor air quality is an issue that needs to be considered in all architectural projects to avoid creating harmful indoor environments.

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